Agricultural Water Use Efficiency

Agricultural water use efficiency efforts involve improvements in technologies and/or management of agricultural water that result in water savings, benefit water supply, water quality, or the environment. This narrative discusses some efficiency improvements, such as those to irrigation equipment, crop water management, farm water management, and district distribution systems.

Current Agricultural Water Use Efficiency Efforts in California

Agriculture is an important element of California's economy, generating $27.6 billion in gross income in 2001, according to the California Agricultural Statistics Service. In 2000, California irrigated an estimated 9.6 million acres of cropland with about 33.7 million acre-feet of applied water.

In California, many growers and irrigation districts have implemented state-of-the-art design, delivery, and management practices to increase production efficiency and conserve water. As a result, they have made, and continue to make, great strides in increasing the economic value and efficiency of their water use. One indicator of agricultural water use efficiency improvement is that agricultural production per unit of applied water (tons/acre-foot) for 32 important California crops increased by 38 percent between 1980 to 2000. Another indicator is that inflation-adjusted gross crop revenue per unit of applied water (dollars/acre-foot) increased by 11 percent between 1980 and 2000.

The Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (AB 3616) and the Federal Central Valley Project Improvement Act (CVPIA) established a framework for improving agricultural water use efficiency. Presently, the Agricultural Water Management Council unites, through a Memorandum of Understanding (MOU), agricultural water suppliers in an effort to improve water use efficiency through implementation of efficient water management practices (EWMPs). The Council recognizes and tracks agency water management planning and implementation of cost effective EWMPs through a review and endorsement procedure. The agricultural water suppliers who are signatory to the MOU, have voluntarily committed to implement locally cost effective EWMPs (see side bar on following page). They represent more than 3.8 million acres of irrigated agricultural land (retail water suppliers) statewide (equivalent to 5.2 million acres of wholesale water agencies.) Some signatories to the MOU have submitted WMPs, most of which have been endorsed. Additionally, 24 signatories subject to federal CVPIA planning requirements have plans that have been endorsed by the Council.

Growers invest in on-farm water management improvements to stay economically competitive. Likewise, local irrigation and water agencies invest in cost-effective system-wide water management improvements. In addition to water savings, implementation of efficiency measures may provide water quality and flow timing benefits. CALFED has identified a set of Quantifiable Objectives (QOs) – numeric targets of water savings, water quality and flow timing benefits – to meet CALFED goals for agriculture. Targeted QOs may be local, regional, and/or statewide. As such, state and federal programs may provide funding for EWMPs that are not locally cost effective and for actions other than the EWMPs.

Substantial financial support for research, development and the demonstration of efficient water management practices in agriculture has come, and continues to come, from the agricultural industry. Support also comes from the early adopters of new technology who often risk their crops, soils and dollars when cooperating to develop and demonstrate technology innovations. Further investments in

Agricultural Water Management Efficient Water Management Practices (EWMPs)

List A - Generally Applicable Efficient Water Management Practices Required of all Signatories of Agricultural MOU

1. Prepare and adopt a Water Management Plan
2. Designate a Water Conservation Coordinator
3. Support the availability of water management services to water users
4. Where appropriate, improve communication and cooperation among water suppliers, water users, and other agencies
5. Evaluate the need, if any, for changes in policies of the institutions to which water supplier is subject

List B - Conditionally Applicable Efficient Water Management Practices – Practices Subject to Net Benefit Analysis and Exemption from Analysis

1. Facilitate alternate land use (drainage)
2. Facilitate use of available recycled water that otherwise would not be used beneficially
3. Facilitate the financing of capital improvements for on-farm irrigation systems
4. Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties
5. Line or pipe ditches and canals
6. Within operational limits, increase flexibility in water ordering by, and delivery to, the water users
7. Construct and operate water suppliers spill and tail water recovery systems
8. Optimize conjunctive use of surface and groundwater
9. Automate canal structures

List C - Practices Subject to Detailed Net Benefit Analysis without Exemption

1. Water measurement and water use report
2. Pricing or other incentives

For detailed information on the Agricultural Water Management Planning and Implementation process, implementation of EWMPs, Net Benefit Analysis and schedules, see the Memorandum of Understanding at AWMC Web site. www.agwatercouncil.org/aboutusmain.htm

research and demonstration are critical, especially in support of university-based research, field station studies, and cooperative extension demonstration projects.

Improvements in the efficiency of agricultural water use result primarily from efforts in three areas:

- **Hardware –** Improving on-farm irrigation systems and district water delivery systems
- **Water management –** Improving management of on-farm irrigation systems and district water delivery systems
- **Crop water consumption –** Reducing crop evapotranspiration

Hardware Upgrades

Due to system limitations, growers are often unable to apply the exact amount of irrigation water when the crop needs it. Water system improvements such as integrated supervisory control and data acquisition systems (SCADA), canal automation, regulating reservoirs, and other hardware and operational upgrades, can provide flexibility to deliver the water when and where it is needed in the appropriate quantities. Most orchards and vineyards, as well as some annual fruits and vegetables in the state, are irrigated using pressurized irrigation systems. Almost all trees and vines established since 1990 are irrigated using micro-irrigation. Between 1990 and 2000, acreage with micro-irrigation in California grew from 0.8 to 1.9 million acres, a 129 percent increase. (see the following table).

Trends in Irrigation Method Acreage (in million acres)

Irrigation method	1990		2000		% change
	Acreage	%	Acreage	%	(in Acreage)
Gravity (furrow, flood)	6.5	67.5	4.9	51.3	- 16.2
Sprinkler	2.3	23.8	2.8	28.8	5.0
Drip/micro	0.8	8.7	1.9	19.9	11.2
TOTAL	9.6	100	9.6	100	

Source: DWR

Example Irrigation Efficiency Improvement

Kern County Water Agency reports significant improvements in irrigation efficiency. An analysis of data in 1986 compared to 1975 showed an 8 percent improvement (from 67 percent in 1975 to 75 percent in 1986). This improvement reduced the total applied water use in the San Joaquin Valley portion of Kern County by about 250,000 acre-feet, enough water to irrigate about 70,000 acres. Since 1986 Kern County has added 61,500 acres of trees and vines. These now make up 37 percent of the total irrigated acreage. Nearly all of this new acreage has low volume drip irrigation systems installed. KCWA estimates the overall on-farm water use efficiency now is about 78 percent.

Many growers use sophisticated automated irrigation systems for irrigation, fertilizer application, and pest management. Advanced technologies used include Geographic Information System (GIS), Global Positioning System (GPS) and satellite crop and soil moisture sensing systems. Satellite-based technologies allow growers to improve the precision of their water application
The shift to pressurized irrigation systems, sprinkler, drip and micro-spray, often requires modernization of the district water delivery systems to provide irrigation water on-demand. Increasingly, irrigation districts are upgrading and automating their systems to enable precise, flexible, and reliable deliveries to their customers. Districts are also lining canals, developing spill recovery and tail water return systems, employing flow regulatory reservoirs, improving the efficiency of pumps, and implementing conjunctive water use programs. With the advancement of irrigation systems and related technologies, there is a potential to improve irrigation efficiencies at both on-farm and district levels.

Growers have made and continue to make significant investments in on-farm irrigation system improvements (e.g., lining head ditches, using micro-irrigation systems). In terms of future improvements, the Cal Poly Irrigation Training and Research Center (ITRC) estimates that an additional 3.8 million acres could be converted to precision irrigation such as drip or micro-spray irrigation. While this may not reduce crop water demand, it could improve the distribution uniformity of water applied, reduce non-beneficial evaporation, and thus allow the grower to apply less water to the field. Research on drip irrigation of alfalfa has shown water application reduction at two to three percent with yields increasing from 19 to 35 percent, an increase in productivity of 30 percent with the same amount of applied water. Conversion of traditional irrigation systems to pressurized systems and installation of advanced technologies on district delivery systems require additional investments in equipment and structure as well as use of additional energy which increases farm production costs and district operational costs.

Water Management

Both on-farm and district systems must be managed to take advantage of new technologies, science, and hardware improvements. Personal computers connected to real-time communication networks and local area networks allow transmission of data from flow sites to a centralized location. These features enable district staff to monitor flow, manage each flow site, and log data on a continuous basis. With such systems, district staff spends less time monitoring and manually controlling individual sites, allowing them to plan, operate the system in a strategic and integrated manner, and reduce operations costs. Such systems improve reliability of the communication systems operation for flexible water delivery, distribution, measurement, and accounting purposes.

Some of today's growers use satellite weather information and forecasting systems to schedule irrigation. Many growers employ evapotranspiration and soil moisture data for irrigation scheduling. Users generate more than 70,000 inquiries per year to the California Irrigation Management Information System (CIMIS), the Department of Water Resources' weather station program that provides evapotranspiration data. Universities, districts, and consultants also make this information available to a much wider audience via newspapers, websites, and other media.

Growers who irrigate by gravity employ laser leveling. The furrows, basins and borders are designed to ensure that water application meets crop water requirements while limiting runoff and deep percolation. Crops are frequently germinated using sprinkler systems. Other growers use plastic mulch to reduce non-essential evaporation of applied water. Many growers take advantage of mobile laboratory services to conduct in-field evaluation of irrigation systems. Once considered innovative technologies, these are now standard practices with growers.

Regulated Deficit Irrigation

Regulated deficit irrigation (RDI) is an irrigation management strategy that some growers use to stress trees or vines at specific developmental stages. The goal is to improve crop quality, decrease disease or pest infestation, reduce production costs, and reduce crop water use without reducing profits. The conventional irrigation management strategy has predominantly been to avoid crop water stress. Research on RDI began in California in the 1990's with initial results showing potential for reducing evapotrans-piration while increasing or maintaining crop profitability and allowing optimum production.

RDI is used primarily on tree and vine crops to control crop quality. On these crops, water stress imposed at specific growth stages has been found to improve crop quality even while plant growth is limited. Wine grapes are a clear example: mild stress imposed through the growing season decreases canopy growth, but produces grapes with higher sugar content, better color and smaller berries with a higher skin to fruit volume ratio.

RDI has been primarily used as a production management practice and the areal extent of its application in California has not been quantified. Before RDI can be applied to other crops, information on its costs, risks, long-term impacts, and potential benefits including water savings must be determined. Once that is done, practical guidelines for growers on how to initiate, operate, and maintain RDI should be developed and disseminated. (See Volume 4: Reference Guide for details on RDI).

Reducing Evapotranspiration

Evapotranspiration is amount of water that evaporates from the soil or transpires from the plant. A grower can reduce evapotranspiration by reducing unproductive evaporation from the soil surface shifting crops to plants that need less water, and/or reducing transpiration - see regulated deficit irrigation sidebar

Potential Benefits of Agricultural Water Use Efficiency

On-farm irrigation improvements can benefit farmers by reducing water applied, reducing groundwater overdraft, increasing crop yield, improving crop quality, lowering the cost of inputs including energy, facilitating the sale of the conserved water And may increase net profit. In the case of water transfers, growers and districts may adopt practices that would otherwise be uneconomic (See Water Transfer strategy). By implementing system improvements, districts provide better service to their customers by increasing delivery flexibility (time and amount of delivery) and reducing seepage and spills. Shifting electric load from peak to off-peak could benefit the farmer and the district by reducing energy costs.

In 2000, the CALFED Water Use Efficiency Program estimated net water savings associated with proven improved agricultural water use efficiency measures to be 120,000 to 565,000 acre-feet per year (see net water sidebar). These net water savings are based on hardware, operational regimes, and irrigation management improvements. Also, there are 47,000 acre-feet of water savings through water use efficiency efforts in the Colorado River Region resulting from the Quantification Settlement Agreement (QSA) that is not included in the CALFED estimates. Likewise, an additional savings of 67,000 acre-feet and 26,000 acre-feet can be achieved by lining the All American Canal and Coachella Branch Canal respectively (For details, see www.usbr.gov/lc/region/g4000/crwda/index.htm).

Applied Water and Net Water Savings

A farmer may apply water to a given field in amounts that is less than, equal or greater than crop evapotranspiration. This amount is called applied water. Often applied water is greater than crop evapotranspiration due to irrigation system inefficiencies, cultural practices, non-uniformity in irrigation hardware and distribution uniformities, and management practices to maintain salt balance in the soil root zone and prevent salinization and degradation of soil.

The water in excess of crop consumptive use or evapotranspiration ending in the salt sinks (saline ground water or ocean) and non-beneficial evaporation constitute opportunity for net water saving.

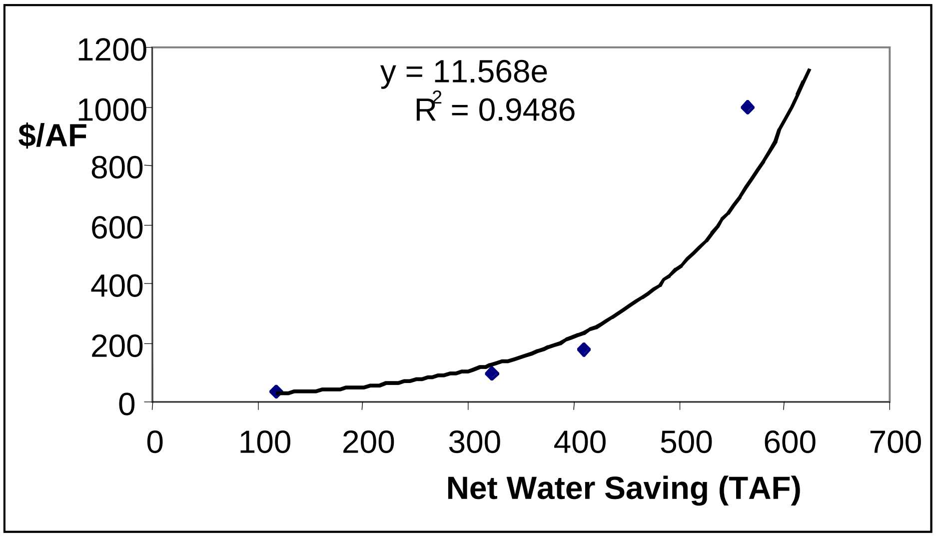
Often, reduction in applied water as a result of efficiency measures is mistaken with net water savings. In some areas, water applied to fields in excess of crop water needs flows to usable surface and groundwater systems and is reused by downstream water users. Such multipurpose reuse also provides opportunities for environmental benefits. Efficiency measures and reduction of applied water in these areas does not yield net water savings and adversely impacts downstream water users, however, it may improve water quality.

Environmental benefits can include increased stream flow and improvements in water temperature and flow timing. Environmental benefits may include water quality improvements through reduced subsurface drainage, surface runoff, and contaminant load, which help dischargers in complying with total maximum daily load requirements. However, improvements in water use efficiency on the field can cause negative environmental effects, such as reduced runoff to downstream water bodies and increased concentration of pollutants in drain water unless the drainage water contaminants are isolated and properly disposed. The CALFED Water Use Efficiency Program estimated applied water reduction (recoverable losses which currently are reused) through changing the time of diversion (rerouting) to provide flow and/or timing benefits to be 1.60 million acre-feet per year. The recoverable losses are reused with multi-benefits such as groundwater recharge, fish and wildlife habitats, and for production of food and fiber. The reduction in applied water in the form of rerouting flows doesn't constitute net water savings.

Benefits resulting from implementation of other advanced technologies in hardware, water management, and crop evapotranspiration, crop shifts and reducing crop transpiration have not been quantified for this narrative.

Potential Costs of Agricultural Water Use Efficiency

The Water Use Efficiency Program estimated net water savings at two levels of expenditure. The first level results when growers and water districts implement efficient water management practices as a part of their standard operation. This level estimates net water savings of 120,000 to 320,000 acre-feet per year at a cost of $35 to $ 95 per acre-foot. The second level results from investment of funds by local , state and federal agencies. This is estimated to achieve additional net water savings ranging from 88,000 to 243,000 acre-feet per year at a cost of $80 to $900 per acre-foot. The cost assumes on-farm efficiency of 85 percent. These cost estimates are based on proven hardware, operation, and management. The estimated costs have a non-linear relationship with the amount of net water savings (see adjacent figure). It should be noted that the water savings and associated costs of All American Canal and Coachella Branch canal lining are not included in these cost estimates.



Implementation of other advanced technologies in hardware, water management, and reducing crop evapotranspiration as proposed in this strategy may result in savings in addition to the savings estimated by the CALFED Program. The additional improvements will increase the cost of crop production or may introduce risk. These additional savings, costs and risks have not been quantified. DWR and CBDA are presently refining the estimates of net water, applied water savings, and associated costs. It is anticipated that the revised estimates will be in the Administrative Draft of this Water Plan Update.

Major Issues Facing Additional Agricultural Water Use Efficiency

Major issues related to improving agricultural water use efficiency in California are:

Funding

Funds dedicated to water use efficiency have fallen below estimates in the 2000 CALFED Record of Decision that called for an investment of $1.5 billion to $2 billion from 2000-2007. The CALFED Framework For Agreement committed state and federal agencies to fund 50 percent (25 percent each), with local agencies funding the remaining 50 percent of CALFED water use efficiency activities. Although the need may be great, small and disadvantaged communities may not to apply for state and federal grants, because of the difficulty of the application and grant management for what are often limited funds. In addition, such districts rarely have the technical and financial abilities to develop plans or implement expensive water management practices.

For some districts, funding for water conservation comes from the ability to transfer water. While transfers to urban areas may reduce the amount of water available to grow crops and may cause third party and environmental impacts, they are expected to play a significant role in financing future water use efficiency efforts.

Implementation

Implementation of agricultural water use efficiency depends on many complicated, interrelated factors. The farmer strives to optimize agricultural profits per unit of land and water without compromising the economic viability of California agriculture, water quality, or the environment. The success depends not only on availability of funds but also on technical feasibility and cost effectiveness, availability of technical assistance, and ability and willingness of growers, irrigation industry, and water district staff. Opportunities also exist through CALFED to implement efficiency measures other than cost-effective EWMPs that provide water quality and flow timing benefits for the local agency or to provide regional and/or statewide benefits.

Designing and installing efficient irrigation and water distribution systems will not necessarily result in improved efficiency if the system is not well managed. The management of water through the district distribution system and irrigation management on the farm are also important.

Reducing evaporation requires precise application of water. Shifting crops requires strategies to promote the practice. Stressing crops (regulated deficit irrigation) requires careful scheduling and application of water and may have additional costs and adverse impact on crop quality or soil salinity. All these actions call for incentive programs and policies. In the case of RDI, research is needed to evaluate the level of current practices, extend of implementation of these practices, and quantify RDI's benefits and impacts.

Many growers and irrigation districts perceive that implementing efficiency measures could impact their water rights. This concern stems from the idea that conserved water may be used by others, causing a loss of rights to the conserved water. This perception is a factor that impedes implementation of conservation.

Measurement, Planning and Evaluation

The state lacks comprehensive data on the acreage under various methods of irrigation, applied water, crop water use, cultural requirements, irrigation efficiency, water use and net water savings, and the cost of irrigation improvements per unit of saved water. Lack of data is an obstacle for assessing irrigation efficiencies and planning further improvement. Collection and management and dissemination of such data to growers, districts, and state planners are necessary for promoting increased water use efficiency. A concern identified by the Advisory Committee members was a lack of statewide guidance to assist regions and districts to collect the data needed for future Water Plan Updates in a usable format.

Resources

The shift to pressurized irrigation systems requires additional energy resources such as electricity, gas, and diesel. They also require pipelines, pumps, filters and filtration systems, and chemicals for cleaning drip systems.

Education and Motivation

Improving agricultural water use efficiency depends on disseminating information on the use, costs, benefits, and impacts of technologies and on providing incentives for implementation. Existing evidence, although limited, indicates a strong response to financial incentives.

Dry-Year Considerations

In dry years, California's water supply is inadequate to meet its current level of use, and agriculture is often called upon to implement extraordinary water use efficiency or even land fallowing. Standard water use efficiency approaches to meet water needs during dry years need to be reviewed and other approaches need to be explored such as alfalfa summer dry-down in hot regions of the State with due consideration for third party impacts.

Recommendations to Achieve Additional Agricultural Water Use Efficiency

The following recommendations can help facilitate additional agricultural water use efficiency:

1. The state should identify and establish priorities for future grant programs and other incentives. Develop a process for quantification and verification of intended benefits of projects receiving state loans and grants.
2. The state should fund technical and planning assistance to improve water use efficiency including: local efforts to implement EWMPs and meet CALFED WUE goals. Provide support in the form of technical and financial assistance to the Agricultural Water Management Council to support its oversight for implementation, monitoring, and reporting of all cost-effective EWMPs. In cooperation with the agricultural community, fund research, development, demonstration, monitoring and evaluation projects that could improve agricultural water use efficiency. Support programs that encourage the development of new cost-effective water savings technologies and practices and evaluate cost-effectiveness of practices. Develop methodology for quantifying water savings and costs associated with hardware upgrades, water management, and evapotranspiration reduction projects proposed in this strategy.
3. The Agricultural Water Management Council should incorporate CALFED Quantifiable Objectives within the Agricultural Water Management Planning and Implementation process. More research should be directed towards determining benefits and impacts of reducing non-productive evaporation and reducing crop evapotranspiration. State's Loans & Grants process should provide ample opportunities for small districts and economically disadvantaged communities, tribes and community-based organizations to benefit from technical assistance, planning activities, and incentive programs, based on environmental justice policies.
4. Agricultural Water Management Council should encourage more water suppliers to join the Memorandum of Understanding and broaden its signatory base. AWMC should get the support of the state and local agencies for full implementation of Efficient Water Management Practices by signatories and encourage the addition of new EWMPs as benefits are identified.
5. Expand CIMIS, mobile laboratory services, and other training and education programs to improve distribution uniformity, irrigation scheduling and on-farm irrigation efficiency.
6. The state should fund large and long-term ET reduction (RDI) demonstration and research plots and other promising programs to reduce evapotranspiration..
7. Based on the long-term ET reduction studies and research, DWR should develop informational guidelines that define the crop water consumption reduction practices (RDI, mulch, alfalfa dry down,

etc.), identify how they can be implemented for each crop; their potential crop benefits and impacts, water savings, and estimate costs for growers and districts to implement.

8. Encourage billing by volume of water delivered rate structures, or other incentives that improve water use efficiency.
9. Collect, manage and disseminate statewide data on acreage under various irrigation methods, the amount of water applied, crop water use, and the benefits and costs of water use efficiency measures. Develop statewide guidance to assist regions and districts to collect the type of data needed, in a form usable for future Water Plan Updates. DWR work with the AWMC to develop a database of information from the Water Management Plans on water use-related data for dissemination and for Water Plan Update.
10. Develop community-based educational and motivational strategies for conservation activities to foster water use efficiency, with the participation of the agricultural and water industries and environmental interests. Develop partnership between state, federal, UC Cooperative Extension Service, farm advisors, irrigation specialists, state educational and research institutions to provide educational, informational, and training opportunities to growers, district staff and others on variety of water and irrigation management practices, operation, and maintenance.
11. The state should explore and identify innovative technologies and techniques to improve water use efficiency by developing new water efficiency measures to correspond with new information. Consider fast track pilot projects, demonstrations, and model programs exploring state-of-the-art water saving technologies and procedures and publicize results widely. Foster closer partnership among growers, water districts and irrigation industry and manufacturers who play an important role in research, development, manufacturing, distribution, and dissemination of new and innovative irrigation technologies and management practices.

Information Sources

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